observed from 9.30 p. m. of the 27th until midnight. The aurora extended from east to west and covered more than half of the sky. At 10.30 p. m. an arch of light, spanning the sky from east to west, was formed in the south, about 30° from the zenith.

Pike's Peak, Colorado: an auroral light was observed in the northeast at 10.20 p. m. of the 27th. At 10.45 p. m. streamers could be distinguished between the clouds that partially obscured the sky. The aurora disappeared at 11 p. m.

Clayton, Jefferson county, New York: Prof. G. K. Gilbert, of the Geological Survey, who observed the aurora of the 27th from this place, says:

I seemed to be looking up into a system of discontinuous curtains, with cross-sections, the most southerly being high, hazy, and cloudlike.

Saint Vincent, Minnesota: at 11.18 p. m. of the 3d an auroral light was seen traversing the sky from east to west through the zenith. This formation continued until a heavy bank of cumulo-stratus clouds which rested on the northern horizon had disappeared, when the arch faded and the auroral light began shooting up from the north in the form of streamers. The aurora disappeared at 2.00 a. m. of the 4th.

Auroral displays were also observed during the month, as follows:

1st.—Eastport, Maine.

2d.—Fort Totten, Dakota; West Union, Iowa; Escanaba, Michigan; Moorhead, Minnesota; Mount Washington, New Hampshire; Syracuse, New York.

3d.—Mount Washington, New Hampshire.

4th.—Webster, Dakota.

5th.—Pekin, Illinois.

7th.—Fort Brady, Michigan.

8th.—Pekin, Illinois.

12th.—Post Mills, Vermont; Tatoosh Island, Washington Territory.

16th.—Wellsborough, Pennsylvania.

19th.—Mackinaw City, Michigan.

20th.—Fort Totten, Dakota.

22d.—Webster, Dakota; Gardiner, Cornish, and Kent's Hill, Maine; Traverse City and Mackinaw City, Michigan; Moorhead, Minnesota; Berlin Mills, New Hampshire; Albany, New York.

23d.—Webster, Dakota.

25th.—Central College, Missouri; West Milton, Ohio.

26th.—Cedar Rapids, Iowa; Wellsborough, Pennsylvania; Burlington, Vermont.

27th.—New Haven, North Colebrook, Southington, and Voluntown, Connecticut; Fort Buford, Fort Totten, and Yankton, Dakota; Riley and Windsor, Illinois; Indianapolis, Indiana; Fort Sill, Indian Territory; Keokuk, Cedar Rapids, Bancroft, Clinton, and Corydon, Iowa; Yates Centre and Salina, Kansas; Portland and Gardiner, Maine; Woodstock, Maryland; Milton, Somerset, Provincetown, Westborough, Fall River, Princeton, Taunton, Deerfield, Cambridge, Quincy, and Amherst, Massachusetts; Grand Haven, Mackinaw City, and Alpena, Michigan; Saint Paul, Minnesota; Central College, Missouri; Valentine, Marquette, and Genoa, Nebraska; Nashua, New Hampshire; Atlantic City, Clayton, and Egg Harbor City, New Jersey; Oswego, Rochester, Cooperstown, North Volney, Factoryville, Menand's Station, Mountainville, Ithaca, Palmyra, and Setauket, New York; Wauseon, Garrettsville, and Elyria, Ohio; Erie, Dyberry, Grampian Hills, and East Brook, Pennsylvania; Block Island, Rhode Island; Nashville, Tennessee; Lunenburg, Newport, Strafford, and Poultney, Vermont; Lynchburg and Wytheville, Virginia; Delavan, Wisconsin.

28th.—Milton, Heath, and Quincy, Massachusetts; Central College, Missouri; Rochester, New York; Fort Spokane, Washington Territory; and Fort Bridger, Wyoming.

THUNDER-STORMS OF JULY, 1886.

[By Jr. Prof. H. A. HAZEN.]

There have been received during July 699 reports of distinct storms from voluntary observers, 355 from Signal Service observers, and 1,654 from special thunder-storm observers, making a total of 2,708. The distribution according to states and districts will be seen from the accompanying table. There have also been a large number of storms noted in the more southerly states, but these do not usually occur under the same conditions as do those further north, and as special observers have been obtained in the Northern States only, those from the southerly states have not been combined in this table. As there are nearly twenty times more special observers in Ohio than in any other state, this will account for the relatively larger number there. The days of greatest frequency were the 13th, 14th, 17th, 26th, and 31st, and those of least frequency the 1st, 2d, 4th, 5th, 6th, and 24th.

The accompanying chart, viii, is presented as giving a view of conditions of pressure, temperature, and wind-direction on the 14th, which may be regarded as a typical case. Lines of equal pressure are drawn full, and those of temperature dotted. The number of storms in each state is given by figures very near the centre. It will be noted that very few of the storms lie to the west of the region marked LOW, but most of them are to the southeast and east of that region. This may be regarded as the normal condition of occurrence of thunder-storms.

On this date there developed thunder-storms of great energy in the Shenandoah Valley, accompanied by high wind, very heavy rain, and in some places hail which was very destructive to crops. A special investigation of these storms has been made, over 640 reports having been received from counties in the Shenandoah Valley and in Maryland. These reports show a fairly uniform motion from southwest to northeast. The storms were noted in the southern edge of Augusta county, Virginia, at eleven hours, and passed off the north edge of Carroll county, Maryland at fifteen hours, which gives a velocity of about forty-four miles per hour. The low area had a velocity less than half that of the storms, this singular fact has been often noted before. The storm was by no means one continuous storm, but the one just described seemed to be the principal storm in a general electrical disturbance extending over Virginia and Maryland, and probably, with less activity, over all the Eastern States. This disturbance gave rise to numerous minor thunder-storms which can be traced as having generally uniform paths in a northeast direction, but which lose their identity much more quickly than the principal storm or series of storms in the centre. Just what relation these sub-storms had to the principal one is a matter of great interest, but it cannot be settled with the present records.

A most careful record was made of the storm at Washington City. First rumblings of thunder were heard soon after noon, but no lightning till 15h.6 when there was a very sharp flash, followed by thunder, which was 2,000 feet to the southeast. A half minute later another crash of thunder was noted four miles away. At 15h.7 a clap was noted about one mile away. At 15.8 the clap was one mile and very nearly overhead. At 15.9 there was another two miles overhead. At 15.10 it was three miles off. The thunder gradually died away after 15.10. The singular fact about this storm was that it seemed to form overhead or slightly to the southeast, there being no definite movement of the storm from southwest or away from the station.

During the summer of 1885 the New England Meteorological Society began collecting detailed records of thunder-storms in New England. A report of the first season's work has been published in the "Proceedings of the American Academy," and the following extract of the conclusions of Professor Davis are taken from that:

While summer storms are much more frequent than winter storms, still they are not uniformly distributed through the season; they appear in greater number and size for a few days, and then are almost or quite absent for a time. The cause of this seems to be found in their dependence on the larger disturbances know as "areas of pressure," as used in the Signal Service publications. It may be concluded that the development of such storms depends, not only on the heat of the summer afternoons, but also on the equilibrium of the atmosphere, as determined by the circulation of cyclonic winds. This fact

Thunder-storms by districts, July, 1886.

District.	State.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	Total.
I	Connecticut					1		1							4	2			6	3			1				3	3		5	4	3	36
	Maine			3	1	1									1	1				5			1				1	1					14
	Massachusetts														1	13	2		11	5						1	3	9	3	17	18	6	89
	New Hampshire								1							1		1	5	3							2	2		3	2		20
	New York							1	1	12	4			10	7	15	9	14	18	2	1	2				6	9	3		22	5		141
	Rhode Island																		1	2										1	1		5
	Vermont							1			2						1		8	5							1			2			20
	Total			3	1	2		3	1	12	7			10	12	32	12	15	49	25	1	2	2			7	19	18	3	50	30	9	325
II	Delaware																																
	Maryland								1	1	2			2	11	9	1		9			4				6	14	3			7	5	75
	New Jersey							1	1		9			1	10	6	4		10	3		2	2	1		3	8	9		3	3	7	83
	North Carolina	1		1	3	3	3		4	1	5	6	5	1	5	5	2					3	1					3	1	2	2	1	58
	Pennsylvania							7		1	6			1	14	9	6	5	9		2		2			2	10	7		2	4	2	89
	Virginia West Virginia			1	1	2	2	1	17	8	15	1	8	16	23	17	6	3	8		1	5	2	8	2	8	16	14	1		6	7	199
	Total	1		2	4	5	5	9	23	11	37	7	13	21	63	46	19	8	36	3	3	14	7	9	2	19	48	36	2	7	22	22	504
III	Illinois						1	2	10	11	3	1	1	8	1					1	8						7	2	3	1	7	2	69
	Indiana							1		14	1	5	5	18				1			11					2	8			4	14	10	94
	Kentucky			2							2				2															1		7
	Ohio	1	2			1	3	56	6	25	7	7	67	154	156	24	12	121	7	1	22	4	25	2	2	6	161	26	10	44	95	41	1,088
	Tennessee	1	3	6	4		3	6	8	7	6	2	1		8						2	3			1		4	4		2	2	10	83
	Total	2	5	8	4	1	7	65	24	57	19	15	74	180	167	24	12	122	7	2	43	7	25	2	3	8	180	32	13	51	119	63	1,341
IV	Michigan									2			3	10			1	1			1	2			1	8	5	2	12	4		2	54
	Minnesota		4	5	3	1			1	1						1		1	2		1			2	3	1		1	1		3	2	33
	Wisconsin			1			1			4	1	3	3	1	1	1	4	1		3	1					2	5		4	1		6	43
	Total		4	6	3	1	1		1	7	1	3	6	11	1	2	5	3	2	3	3	2		2	4	11	10	3	17	5	3	10	130
V	Dakota	1		1				1	2								1	2	3					1	1			2	1	1		2	19
	Iowa		1	11		1	2	1	7	36	9		30	1	4	8		1			1	2		18	2	14	3	2	9	13	20	41	237
	Nebraska				1		1			1					3	1		1	3	1	2		1	4	3	2		1	1	7	3	8	44
	Total	1	1	12	1	1	3	2	9	37	9		30	1	7	9	1	4	6	1	3	2	1	23	6	16	3	5	11	21	23	51	300
VI	Arkansas							1			1						1	2			1			1	1	1	1				1	3	14
	Indian Territory						1	1											2	1			1		3						1	1	11
	Kansas		2					5	1										9	5			1	7	2	1			1	14	8	4	60
	Missouri							1			1	1		1	1	1				4	4			1	1		1			1	1	3	1	23
	Total		2				1	8	1		2	1		1	1	1	1	2	11	10	5		2	9	7	3	1		2	15	13	9	108
	Grand total	4	12	31	13	10	17	87	59	124	75	26	123	224	251	114	50	154	111	44	58	27	37	45	22	64	261	94	48	149	210	164	2,708

was first definitely announced by Marié Davy in 1864, who says: "The appearance of storms always coincides with the presence of rotary winds, known under the name of '*bourrasques*,'" and has been confirmed by other European services and by the Signal Service. The greatest number of our summer thunder-storms occur when a centre of low pressure lies to the north or northeast of us. But there are also examples of storms occurring in areas of high or equable pressure, as on August 1, 1885; these would seem to correspond to the "Wärme-Gewitter" of Mohn, and to depend on a local warming of the lower air sufficient to bring about the unstable equilibrium that in the other cases (Wirbel-Gewitter) depends on the arrangement of upper and lower currents in the cyclonic circulation. A more peculiar exception to the general rule of occurrence is found on certain dates when a well-developed low pressure centre passed north of New England without bringing any local storms to us. The most pronounced example of this condition was on July 17th, in the middle of a long period remarkably free from storms; it was one of the hottest days of the summer, and yet passed without reports worth mentioning. The occurrence of two neighboring low pressure areas may interfere with the arrangement of upper winds needed for the development of the heavy clouds of thunder-storms, as on June 15th, with low pressure centres northeast and northwest, and no storms, and on July 10th, with low pressure centres north and south, and we had only light rains.

The direction of motion of thunder-storms seems to be about at right angles to the radius joining them with the low pressure centre. The relation of the velocity of local storms to the gradients and the velocity of the low areas in which they occur, needs still further investigation. The same may be said of the conditions that determine the arrival of some storms early in the day, and of other storms late; the passage of some storms with apparently undiminished strength off the sea-coast and their endurance into the evening, while others act in the opposite way; and the maintenance of high temperatures after some storms (morning squall of July 21st, and morning storm of August 4th) while most are followed by decidedly cooler weather.

The surface winds flowing towards the storm at a little distance from it, and the squall commonly met, blowing outwards in front of the rain-area, are well-defined on many occasions. The relation of the rain to the out-blowing squall is variable; in many cases, the former seems to be the effect of the latter; but in others we have heavy rain and no squalls; sometimes the squall is felt at only a few stations, while the heavy rain is general. Many observers speak of a connection between lightning flashes and an increase in the rainfall immediately following; it is quite possible that this relation exists, but the evidence usually quoted to prove it does not seem conclusive.

The more general distribution of storms in the areas of low pressure, their total duration, and the possibility of their surviving the cooler hours of the night, are problems that can be better determined by the work of the Signal Service in reviewing the more detailed studies of local services. It is hoped that many of these problems may find their solution in that larger fund of material towards which this report is offered as a contribution.

Thunder-storms are of so rare occurrence on the Pacific coast, only twenty-three storms being reported from twenty stations in California, Oregon, and Washington Territory, during 1885, and twenty-seven during June and July, 1886, that the following abstract of a report from B. S. Pague, Signal Service observer at Roseburg, Oregon, is of special interest:

Thunder-storms at this station average six a year, and a severe storm is rarely felt. From January, 1883, to July, 1886, the number of storms were: April, 5; May, 4; June, 3; July, 6; August, 3; September, 1; October, 1. In 1883, there were 7; 1884, 7; 1885, 3; 1886, 7. The following report is based on the storms of July 18th, 19th, and 20th. This city is situated in a valley of five hundred acres, surrounded by low ranges of mountains two or three hundred feet in altitude above the station. About fifty miles north of Roseburg begins the Willamette Valley, which is one hundred and fifty miles long, and from fifteen to forty miles wide, extending to the Columbia River. It is flat, has comparatively few trees, is very warm in summer, and is quite thickly settled. Light thunder-storms generally occur in the afternoon, moving from south to north, and severe lightning is rarely observed; records show only two cases in many years, namely, July 4, 1882, and July 20, 1886. In 1882, many trees were struck, which was the first time known in this vicinity. The thunder consists of slow, rumbling sounds. The wind rarely attains a great velocity; on August 2, 1884, however, its rate was forty-one miles per hour. Hail with thunder-storms is almost unknown.

For seven days previous to July 18, 1886, the mean humidity was 54 per cent., and for four days previous it was 47 per cent. The humidity in the morning is from 80 to 96 per cent., while on the morning of the 18th it was 66 per cent. at 4 a. m., 39 per cent. at 8 a. m., 29 per cent. at noon, and 30 per cent. at 4 p. m.; the rain beginning at 3.55 p. m. The pressure had a steady fall, and the temperature a steady rise, from the 12th to the 18th, when the latter reached 100°. The storm of the 18th moved from north-northeast to south-southwest, east of the station, no lightning being visible. Thunder was first heard at 2.27 p. m. and last at 3.25 p. m. Rain began at 3.55, ended at 4.35, amount a trace. Wind before, northeast; after, east; from 5 to 12 miles per hour. Temperature before, 99°; after, 86°. Heavy rain fell to the eastward. The storm of the 19th suddenly appeared over the crest of a hill three hundred feet in elevation and one-eighth mile to southeast. It was heard, a few minutes before it appeared, by the gale blowing through the timber. Its course was curved from southeast to northeast. While the sun shone in the west the eastern sky was black as the darkest night. Rain (.15 inch) fell

from 4.31 p. m. to 5.04 p. m. Hail, size and shape of a pea, fell for thirty seconds previous to the rain. The highest wind, lasting five minutes, was twenty-four miles per hour. Direction of wind before storm, northeast; after, southeast. Temperature before storm, 85°; after, 71°. During the storm the low clouds had a whirling motion, branches were broken and grain was prostrated. On July 20th, at 4.48 a. m., one of the most violent thunder-storms, consisting of rapid lightning flashes and peal on peal of thunder, broke on the station. It lasted three hours, and was most severe from 5.40 to 6.15. Rain (1.00 inch) began at 4.19, falling in torrents till 8.15, and ending at 9.15 a. m. No hail; light wind, east and south; temperature before, 64°.5; after, 68°.

CHART OF ELECTROMETER READINGS.

[By Prof. T. C. MENDENHALL, Assistant.]

The first diagram of chart vi shows the results of a set of observations made on the top of the Washington Monument. The elevation of the collector is about five hundred and five feet above the ground. The observations were taken every five minutes, except between 11.30 a. m. and 12 m., and between 1.30 and 2 p. m., when the interval was one minute. The day was cloudless but hazy, the wind from the southwest and light. During the forenoon the needle oscillated almost continually, indicating variable, high, positive potentials. During the afternoon the indications were much less in value, and more regular in character, the weather remaining, however, apparently the same. About 12.30 p. m. there was a period of about eight minutes during which the needle was again very active, after which the indications became again of less value and less variable.

The second diagram of chart vi represents the values obtained at the Sloane Laboratory, Yale College, during the passage of a thunder-storm, July 14, 1886. Thunder was first heard at 6.45 p. m.; loudest from 7 to 7.05 p. m., and last heard at 7.15 p. m. The wind, before the storm, was from the east, velocity about twelve miles an hour; during the storm from the east and southeast, and after the storm from the east. Rain began at 6.54 p. m. and ended at 8.30 p. m. Lightning was recorded at 7.02 and 7.07 p. m.

The following notes are abstracted from the report of the observer at that station:

Negative potentials occurred on the following dates: June 23d, heavy rain and east wind. June 30th, at 1 p. m., very slight indications, weather clear, wind south. July 3d, 11 a. m., very slight indications, weather clear, wind northwest. July 9th, 9 a. m., wind northeast, light rain; 3 p. m., wind south, light rain. July 12th, 1 p. m., slight indications, weather clear, wind south. July 16th, throughout the day large values, continued rain. July 21st, at 11 a. m., light rain, southeast wind. July 27th, at 11 a. m., large values, heavy rain. All days on which rain fell were characterized by negative potentials. A faint auroral display observed at 2 a. m., June 30th; was preceded, during the afternoon of the 29th, by negative potential.

At Boston, Massachusetts, on July 27th, the electrometer gave evidence of unusual disturbance, and special readings were made at intervals of two minutes from 9 a. m. until 11 a. m.

The following abbreviated table is from the observer's record:

Time.	Volts.	Remarks.	Time.	Volts.	Remarks.
A. M.			*P. M.*		
9.00	— 10	Threatening.	2.00	+ 25	Light rain.
9.02	— 8		2.06	+150	
9.04	0		2.08	+ 60	Heavy rain.
9.08	+ 8	Light showers.	2.10	+400	
9.10	+ 14		2.12	— 95	
9.12	— 40	Rain ended.	2.14	+360	
9.20	— 12		2.16	—180	Light rain.
9.30	0		2.18	— 60	
9.38	+ 20		2.20	— 5	
9.40	0		2.22	+ 40	Heavy rain.
9.46	+ 40		2.24	+ 65	
9.50	— 16		2.26	+ 25	
10.00	— 20		2.28	+ 48	
10.10	— 5		2.30	+ 22	Light rain.
10.18	+ 20	Light rain began.			
10.28	— 20				
10.30	+ 15				
10.40	+ 5				

There was a very brilliant aurora during the night of July 27th. At 6.40 a. m. July 28th the potential exceeded 1,100 volts. From 7 a. m. until 8.15 a. m. the mean potential of the air exceeded 1,000 volts. At 9 a. m. it averaged about 265. It continued falling steadily. At 11 a. m. it was zero, and at 1 p. m., minus ten, where it remained during the rest of the day.

The third diagram of chart vi represents the potential variations during a thunder-storm at Cornell University, Ithaca, New York. The observations, in detail, are given below:

During the month negative readings occurred on the following dates: July 7th, at 9 a. m., in value about 16 volts, the weather hazy, the wind northwest and fresh; low positive potentials during the rest of the day, the weather remaining cloudy and threatening. July 14th, at 11 a. m., mean value 220 volts, weather cloudy, and at times raining. At 1 p. m., 1,425 volts, and a minute later 670 volts, changing to positive 400 at 1.02 p. m., 500 at 1.03, and zero at 1.04 p. m. July 17th, during the forenoon, slight negative values, becoming greater; weather clear and warm, with light haze. July 18th, at noon, during thunder-storm; 3 p. m., 3,250 volts during thunder-storm. July 20th, at 11 a. m., slightly negative for a few moments. July 28th, at 9 a. m., weather clear, calm, and hazy. Rain occurred on July 14th, during the night of the 15th, on the 17th, 18th, 21st, 25th, and 26th.

During the thunder-storm of July 14th the following observations were made:

Time.	Volts.	Remarks.	Time.	Volts.	Remarks.
A. M.			*A. M.*		
10.57	+ 850	Rain commenced.	11.37	+ 125	
11.03	— 300	Rain increasing.	11.38	+ 225	
11.13	+ 350		11.40	+ 300	
11.17	0	Rain diminishing.	11.42	+ 120	
11.18	— 125		11.44	— 80	
11.19	— 125		11.46	— 170	
11.20	+ 50	Rain increasing.	11.48	— 85	
11.21	+ 375		11.50	— 150	Rain increasing.
11.22	+1300	Very heavy rain.	11.51	— 300	
11.23	+1550		11.52	0	
11.25	+1400	Rain diminishing.	11.53	+ 270	
11.26	+1300		11.54	+ 125	
11.28	+1600		11.55	— 150	
11.30	+1000	Rain diminishing.	11.56	— 200	
11.31	+ 700		11.58	— 175	
11.32	+ 250		12.00 m.	— 180	
11.33	+ 25		1.00 p. m	—1425	High southeast wind, light rain.
11.34	— 50	Light rain.			
11.35	— 25		1.05 p. m	+ 10	
11.36	+ 25		3.00 p. m	+ 45	

OPTICAL PHENOMENA.

SOLAR HALOS.

Solar halos were observed in the various states and territories during the month, as follows:

Alabama.—Mobile, 10th.

Arizona.—Yuma, 12th, 20th.

Connecticut.—New Haven, 2d; New London, 29th.

Dakota.—Webster, 30th.

Florida.—Sanford, 1st, 5th; Key West, 1st, 8th, 9th.

Georgia.—Augusta, 2d; Savannah, 11th.

Illinois.—Pekin, 1st to 5th, 7th, 8th, 10th, 12th, 20th, 24th, 25th, 27th.

Indiana.—Jeffersonville, 13th, 16th.

Iowa.—Keokuk, 23d.

Kansas.—Wyandotte, 20th, 21st, 22d; Salina, 27th; Yates Centre, 30th.

Maine.—Cornish, 9th, 14th, 21st; Portland, 9th, 21st; Gardiner, 21st.

Massachusetts.—Milton, 5th, 18th, 25th; Heath, 19th; Provincetown, 25th, 26th, 28th, 29th, 30th.

Michigan.—Escanaba, 8th; Marquette, 8th, 29th; Grand Haven, 11th.

New Hampshire.—Mount Washington, 25th.

New Jersey.—Clayton, 1st, 15th; Beverly, 13th.

New York.—Mountainville, 1st; Setauket, 1st, 2d; Palermo, 2d.

North Carolina.—New River Inlet, 9th, 15th, 18th, 25th.

Ohio.—Wauseon, 2d, 25th, 29th.

Oregon.—Roseburg, 4th, 26th; East Portland, 6th.